1. *Density Determinations*

Objective

Density is an important property of matter, and may be used as a method of identification. In this experiment, you will determine the densities of regularly and irregularly shaped solids as well as of pure liquids and solutions.

Introduction

The density of a sample of matter represents the mass contained within a unit volume of space in the sample. For most samples, a unit volume means 1.0 mL. The units of density, therefore, are quoted in terms of grams per milliliter (g/mL) or grams per cubic centimeter (g/cm^3) for most solid and liquid samples of matter.

Since we seldom deal with exactly 1.0 mL of substance in the general chemistry laboratory, we usually say that the density of a sample represents the mass of the specific sample divided by its particular volume.

$$\text{density} = \frac{mass}{volume}$$

Because the density does in fact represent a *ratio*, the mass of any size sample, divided by the volume of that sample, gives the mass that 1.0 mL of the same sample would possess.

Densities are usually determined and reported at 20°C (around room temperature) because the volume of a sample, and hence the density, will often vary with temperature. This is especially true for gases, with smaller (but still often significant) changes for liquids and solids. References (such as the various chemical handbooks) always specify the temperature at which a density was measured.

Density is often used as a point of identification in the determination of an unknown substance. In later experiments, you will study several other physical properties of substances that are used in the identification of unknown substances. For example, the boiling and melting points of a given substance are characteristic of that substance and are used routinely in identification of unknown substances. Suppose an unknown's boiling and melting points have been determined, but on consulting the literature, it is found that more than one substance has these boiling and melting points. The *density* of the unknown might then be used to distinguish the unknown. It is very unlikely that two substances would have the same boiling point, melting point, and density.

Density can also be used to determine the concentration of solutions in certain instances. When a solute is dissolved in a solvent, the density of the *solution* will be different from that of the *pure solvent* itself. Handbooks list detailed information about the densities of solutions as a function of their composition (typically, in terms of the *percent solute* in the solution). If a sample is known to contain only a single solute, the density of the solution could be measured experimentally, and then the handbook could be consulted to determine what concentration of the solute gives rise to the measured solution density.

The determination of the density of certain physiological liquids is often an important screening tool in medical diagnosis. For example, if the density of urine differs from normal values, this may indicate a problem with the kidneys secreting substances which should not be lost from the body. The determination of density (specific gravity) is almost always performed during a urinalysis.

Several techniques are used for the determination of density. The method used will depend on the *type of sample* and on the level of *precision* desired for the measurement. For example, devices have been constructed for determinations of the density of urine, that permit a quick, reliable, routine determination. In general, a density determination will involve the determination of the mass of the sample with a balance, but the method used to determine the volume of the sample will differ from situation to situation. Several methods of volume determination are explored in this experiment.

For *solid* samples, different methods may be needed for the determination of the volume, depending on whether or not the solid is regularly shaped. If a solid has a *regular shape* (e.g., cubic, rectangular, cylindrical), the volume of the solid may be determined by geometry:

$$\text{For a cubic solid, volume} = (\text{edge})^3$$
$$\text{For a rectangular solid, volume} = \text{length} \times \text{width} \times \text{height}$$
$$\text{For a cylindrical solid, volume} = \pi \times (\text{radius})^2 \times \text{height}$$

If a solid does *not* have a regular shape, it may be possible to determine the volume of the solid from Archimedes' principle, which states that an insoluble, nonreactive solid will *displace* a volume of liquid equal to its own volume. Typically, an irregularly shaped solid is added to a liquid in a volumetric container (such as a graduated cylinder) and the *change* in liquid level is determined.

For liquids, very precise values of density may be determined by pipeting an exact volume of liquid into a sealable weighing bottle (this is especially useful for highly volatile liquids) and then determining the mass of liquid that was pipeted. A more convenient method for routine density determinations for liquids is to weigh a particular volume of liquid as contained in a graduated cylinder.

SAFETY PRECAUTIONS

- **Wear safety glasses at all times while in the laboratory.**
- **The unknown liquids may be flammable, and their fumes may be toxic. Keep the unknown liquids away from open flames, and do not inhale their vapors. Dispose of the unknown liquids as directed by the instructor.**
- **Dispose of the metal samples only in the container designated for their collection.**

Apparatus/Reagents Required

Unknown liquid sample, unknown metal sample, sodium chloride

Procedure

Record all data and observations directly in your notebook in ink.

A. Determination of the Density of Solids

Obtain a regularly shaped solid, and record its identification number. With a ruler, determine the physical dimensions (e.g., length, width, height, radius) of the solid to the nearest 0.2 mm. From the physical dimensions, calculate the volume of the solid.

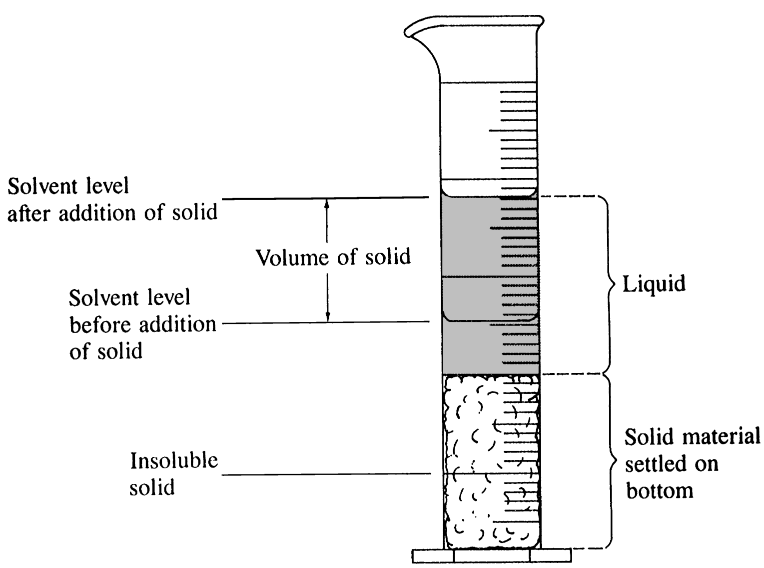
Determine the mass of the regularly shaped solid to at least the nearest mg (0.001 g). From the mass and volume, calculate the density of the solid.

Obtain a sample of metal pellets (shot) and record its identification code number. Weigh a sample of the metal of approximately 50 g, but record the actual mass of metal taken to the nearest mg (0.001 g).

Add water to your 100-mL graduated cylinder to approximately the 50-mL mark. Record the exact volume of water in the cylinder to the precision permitted by the calibration marks of the cylinder.

Pour the metal sample into the graduated cylinder, making sure that none of the pellets sticks to the walls of the cylinder above the water level. Stir/shake the cylinder to make certain that no air bubbles have been trapped among the metal pellets. (See Figure 1-1.)

FIGURE 1-1
Measurement of volume by displacement. A nonsoluble object displaces a volume of liquid equal to its own volume.



Read the level of the water in the graduated cylinder, again making your determination to the precision permitted by the calibration marks of the cylinder. Assuming that the metal sample does not dissolve in or react with water, the change in water levels represents the volume of the metal pellets.

Calculate the density of the unknown metal pellets.

After blotting them dry with a paper towel, turn in the metal pellets to your instructor (*do not discard*).

B. Density of Pure Liquids

Clean and dry a 25-mL graduated cylinder (a rolled-up paper towel should be used). Weigh the dry graduated cylinder to the nearest mg (0.001 g).

Add distilled water to the cylinder so that the water level is above the 20-mL mark but below the 25-mL mark. Determine the temperature of the water in the cylinder.

Reweigh the cylinder to the nearest milligram.

Record the exact volume of water in the cylinder, to the level of precision permitted by the calibration marks on the barrel of the cylinder.

Calculate the density of the water. Compare the measured density of the water with the value listed in the handbook for the temperature of your experiment.

Clean and dry the graduated cylinder.

Obtain an unknown liquid and record its identification number. Determine the density of the unknown liquid, using the method just described for water.

C. Density of Solutions

The concentration of solutions is often conveniently described in terms of the solutions' *percentage composition* on a weight basis. For example, a 5% sodium chloride solution contains 5 g of sodium chloride in every 100 g of solution (which corresponds to 5 g of sodium chloride for every 95 g of water present).

Prepare solutions of sodium chloride in distilled water consisting of the following percentages by weight: 5%, 10%, 15%, 20%, 25%. Prepare 25 mL of each solution (you do *not* have to prepare 100 g of each solution to be able to use the percentage composition). Make the weight determinations of solute and solvent to the nearest milligram.

Using the method described earlier for samples of *pure* liquids, determine the density of each of your sodium chloride solutions. Record the temperature of each solution while determining its density.

Construct a graph of the *density* of your solutions versus the *percentage of NaCl* the solution contains. What sort of relationship exists between density and composition?

Use a handbook of chemical data to determine the true density of each of the solutions you prepared. Calculate the error in each of the densities you determined.

Density Determinations

Date:	....	Student name:	....
Course:	....	Team members:	....
Section:	....		....
Instructor:	....		....

Prelaboratory Questions

1. A metal sphere weighing 15.45 g is added to 21.27 mL of water in a graduated cylinder. The water level rises to 24.78 mL. Calculate the *density* of the metal.

2. An empty beaker weighs 32.4257 g. A 10-mL pipet sample of an unknown liquid is transferred to the beaker. The beaker weighs 40.1825 g when weighed with the liquid in it. Calculate the *density* of the unknown liquid.

3. A term that is easily confused with density is *specific gravity*. For example, urinalysis reports commonly give the specific gravity of the sample rather than the density. What is meant by specific gravity? What are the units of specific gravity?

Density Determinations

Date: ....
Course: ....
Section: ....
Instructor: ....

Student name: ....
Team members: ....
....
....

Results/Observations

A. Density of Solids

ID number of regular solid .... Shape ....

Dimensions of solid ....

Calculated volume of solid ....

Mass of solid .... Density ....

ID number of metal pellets .... Mass ....

Initial water level .... Final water level ....

Calculated density of metal ....

B. Density of Pure Liquids

Mass of empty graduated cylinder ....

Mass of cylinder plus water ....

Volume of water .... Density ....

Temperature .... Handbook density ....

ID number of unknown liquid ....

Mass of cylinder plus liquid ....

Volume of liquid .... Density ....

C. Density of Solutions

% NaCl	*Density measured*	*Temperature*	*Density handbook value*	*% error*
5%				
10%				
15%				
20%				
25%				

Questions

1. What error would be introduced into the determination of the density of the regularly shaped solid if the solid were *hollow*? Would the density be too high or too low?

2. What error would be introduced into the determination of the density of the irregularly shaped metal pellets if you had not stirred/shaken the pellets to remove adhering *air bubbles*? Would the density be too high or too low?

Student name: .... Course/Section: .... Date: ....

3. An alternative procedure for determining the density of a liquid would be to pipet a sample of the liquid into a weighed flask; then reweigh the flask to determine the mass of liquid transferred. Would this alternative procedure be likely to give greater precision in the density determination? Why? Why do you suppose this alternative procedure was not used?

4. Your data for the density of sodium chloride solutions should have produced a straight line when plotted. How could this plot be used to determine the density of any concentration of sodium chloride solution?

5. Using a handbook of chemical data, look up the densities of the sodium chloride solutions listed below. Give the solution temperature listed in the reference work.

5% NaCl solution Density .... g/mL

10% NaCl solution Density .... g/mL

15% NaCl solution Density .... g/mL

20% NaCl solution Density .... g/mL

25% NaCl solution Density .... g/mL

Temperature for the above densities of NaCl solutions .... °C

Reference ....